PART I. USER'S GUIDE

CHAPTER 1
INTRODUCTION

1.1 Purpose

Radio frequency (rf) transmission between 3 and 30 MHz by ITU convention is called high frequency (HF) or "shortwave" radio. HF is the widely used communication band for long distances. The use of HF radio transmissions has been experiencing a renewal of interest and investment because of the realization that satellite and terrestrial communication modes are vulnerable to electronic countermeasures and physical destruction. HF radio transmissions, although of much lower overall reliability and limited data bandwidth than other communication bands, allow communication over long distances and can be expected to function throughout a global conflict, and even to recover more rapidly from the effects of nuclear detonations [Bennett *et al.*, 1987]. This level of survival and recovery may not be the case for satellite and terrestrial communication modes.

The ionosphere is a key element of HF skywave communications. Transmitted HF radio waves hitting the ionosphere are bent or refracted. When they are bent sufficiently, the waves are returned to earth at a distant location. Often at the distant location they are reflected to the sky again, only to be returned to earth yet again, even farther from the transmitter. This HF skywave hopping or skipping (*i.e.,* transmitter-to-ionosphere-and back to receiver on the ground) can increase communication to very long distances (1 hop: <4000 km, 2 hops: 4000 to 7000 km, 3 hops: 7000 to 12000 km). This propagation phenomenon is such that many amateur radio operators ("hams") at certain times carry out satisfactory communication at distances greater than halfway around the world with 1 W to 2 W of radiated power. In fact, if the medium were noiseless and there were no interference, the required power could even be less [Freeman, 1997].

Unfortunately the HF environment is not noiseless and interference does exist; additionally, other details of the HF propagation environment are also constantly changing. Optimum HF propagation can vary by location, frequency, season, time of day; can have cyclic variations; and can be affected by unexpected ionospheric disturbances. This handbook's Annex 1, "The Communications Media," describes in detail the HF propagation medium and how these variations and disturbances will affect it. The amount of bending or refraction of the HF signal is frequency dependent. During certain periods of the day or night, one frequency might propagate well but perhaps during other periods of day or night propagation might be poor or non-existent. A generalization might be: *the high-end frequencies are best during the day, low-end frequencies are best during night,* but even this generalization is not an accurate descriptor all of the time.

1.2 Scope and definition of adaptive systems

How, then, can we use this medium for reliable communication? A few years ago, communication in the HF band relied on the tracking of propagation variations by using computer propagation modeling programs to interpolate variations, and by relying on the skills of the operators to listen to noisy channels for communication links. The characteristics of this communication mode might include:

1. the mode requires very labor-intensive operator duties,
2. the propagation is variable in nature,
3. the mode is vulnerable to jamming, and
4. blackouts are possible in an ionized atmosphere such as a nuclear explosion.

To rectify at least some of these problems, technology has now provided an improved adaptive radio and other improvement schemes to simplify the lives of HF communicators. A new class of radio, under microprocessor control, has a more robust modulation/demodulation scheme, includes error coding, and includes rapidly switching antenna tuners and couplers. The new class of radio has also added automation features such as frequency selection/management, link establishment, link maintenance, and networking protocols to relieve the operator of these duties.

1.3 Historical perspectives and background

To insure that this new technology would not develop completely unchecked with a number of manufacturers all producing incompatible radio systems, the development cycle also included the development of HF radio standards. The United States has produced Federal Standards and military Standards defining all the protocols that comprise Automatic Link Establishment (ALE) radio operations [Young *et al.*, 1994]. Corresponding international standards are in the process of being produced. The cooperation in the standards process between government agencies and industry manufacturers has worked so well that the HF communications systems designer can concentrate on the system-level details of the design, using a document agreed upon by industry leaders.

1.4 Organization of this handbook

This handbook describes the requirements and attributes of automatic and adaptive HF radio systems. Within the chapters, the HF ionospheric channel and communications propagation medium are discussed, as are the details of how automatic and adaptive equipment can be used to track the variations in the HF communication medium. Automatic Link Establishment is discussed, as are advanced HF modems and networks. The handbook contains an Implementer’s/System Engineer’s handbook which can be used by a system designer to design and implement an HF ALE system. A Network Manager's handbook shows the details associated with designing and implementing a network of HF ALE radio equipment. Annexes to this handbook describe:

- the communications media [Annex 1],
- propagation-prediction systems [Annex 2],
- elements in an HF radio system [Annex 3],
- examples of typical HF radio systems and networks [Annex 4],
- linking protection for HF ALE radio networks [Annex 5],
- HF e-mail [Annex 6],
- HF Internet access [Annex 7].

Other annexes provide:

- a common glossary for HF radio [Annex 8],
- a bibliography/list of references for this handbook [Annex 9].

1.5 Product Disclaimer

Certain commercial equipment, instruments, services, and materials are identified in this handbook to specify adequately the technical aspects discussed herein. In no case does such identification imply recommendation or endorsement by the U.S. Department of Commerce or by the National Telecommunications and Information Administration, nor does it imply that the material or equipment identified is necessarily the best available for the purpose.